HENNING & MORGAN

Tests of Several Types of Small Gasolene Engines

Mechanical Engineering

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TESTS OF SEVERAL TYPES OF SMALL GASOLENE ENGINES

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WARREN KENYON HENNING and HORACE HEALY MORGAN

ENTITLED TESTS OF SEVERAL TYPES OF SMALL GASOLENE ENGINES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

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OUTLINE OF THESIS.

TESTS OF SEVERAL TYPES OF SMALL GASOLINE ENGINES.

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Object of Thesis.

Gasoline engines in Theory.

Description of Engines and Apparatus.

Sketches of Engines and Apparatus.

Log Sheets.

Calculations.

Sheets of Results.

Curves of Results.

INTRODUCTION.

Owing to the limited data on the preformances of small gasoline engines of from two to ten horse power, it is proposed to investigate the preformance of these engines under the ordinary working conditions in order to determine, the Efficiency, the cost of Brake Horse Power and incidentally the distribution of the heat of the fuel.

As the cost per horse power depends upon the economical use of fuel, those conditions alone which determine the efficiency and the methods of varying these conditions to increase the efficiency, will be discussed.

In any engine, no matter how well it may be constructed, there is always a loss of power due to several causes which can not be changed in this engine. There are losses due to the friction of all the moving parts and also due to the friction of the gases both in entering and leaving the cylinder. Another loss of power is due to the absorption of heat by the jacket water and the heat carried out of the cylinder by the charge on the exhaust stroke. The balance of the heat put in the cylinder is delivered in usefull work.

The losses vary a good deal in different engines and in the same engine under different conditions but approach the values given.

		%
Friction:		
	Mechanical.	10-20
	Fluid	4-15
	Exhaust.	20-30
		34-65
Jacket Water.		46-23
Usefull work.		22- 8

The function the jacket water is to carry away the excessive amounts of heat generated during the explosion thus protecting the engine from the very high temperatures generated by the explosion. The jacket water would not be needed if the charge coubd be diluted with sufficient air so that the temperature at the explosion would be low, about 1000 degrees Fahrenheit, but when the mixture is this weak it will not explode.

In the following pages the formula for the efficiency is derived.

where $k = 1.41$

P_d = lbs of compression.

P_a = atmospheric pressure.

r = efficiency.

$$r = 1 - \left(\frac{P_a}{P_d}\right)^{\frac{K-1}{K}}$$

This formula shows the efficiency varies with the compression since P_a remains constant for the test. Thus if by some means the compression can be increased, the amount of work given up by the charge will be increased. According to the formulae there is no limit to this increase, but there is a practical limit of 80-90 pounds per sq. in. of compression.

GASOLINE ENGINES IN THEORY.

OTTO CYCLE: All the engines in this test are designed to run on the Otto cycle. The Otto Cycle is composed of four processes, two constant volumne and two adiabatic expansions.

Where y = Efficiency.

p = Pressure per sq. ft.

V = Volume in Cu. ft.

T = Absolute temperature.

C_p = Specific heat at constant pressure.

C_v = Specific heat at constant volume.

$K = \frac{C_p}{C_v} = 1414$

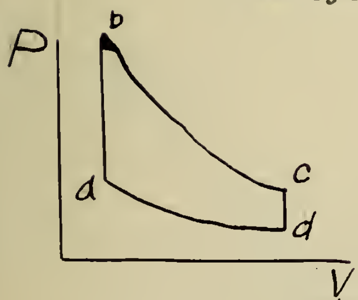
W = work done.

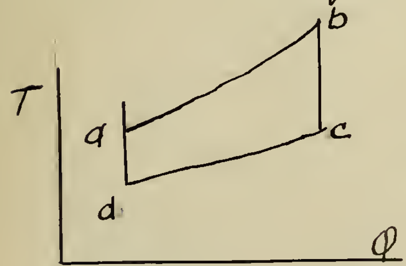
Q = B.T.U. of heat.

J = Mechanical equivalent of heat = 778 ft. lb.

= Entropy.

The cycle in pV and T φ coordinates is shown below.





The medium in the state (a) is heated at constant volume, the pressure and temperature rising as shown by (a-b). The heat absorbed during the process is ,

$$Q_{ab} = C_v (T_b - T_a)$$

From (bc) the medium expands adiabatically. For this process $Q_{bc} = 0$,

$$W_{bc} = \frac{P_bV_b - P_cV_c}{K - 1}$$

In this state (c) the medium is put in

communucation with a cold body and cools at constant volume. The heat absorbed is, $Q_{cd} = C_v(T_d - T_c) = C_v(T_c - T_a)$ The work done is, $W_{cd} = 0$. Finally the medium is compressed adiabatically from (d-a) and for this change of state, $Q_{da} = 0$. $W_{da} = \frac{P_dV_d - P_aV_a}{K-1}$. The heat changed into work is,

$$J(Q_{ab} - Q_{bc} - Q_{cd} - Q_{da}) = Jc_v \ (T_b - T_a) - (T_c - T_a)$$

Work of Cycle,

$$W = W_{ab} - W_{bc} - W_{cd} - W_{da} = \frac{(P_bV_b - P_cV_c) - (P_aV_a - P_dV_d)}{K - 1}$$

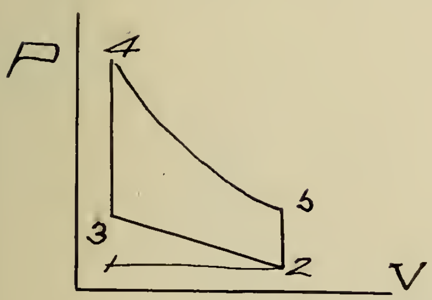
The efficiency is,

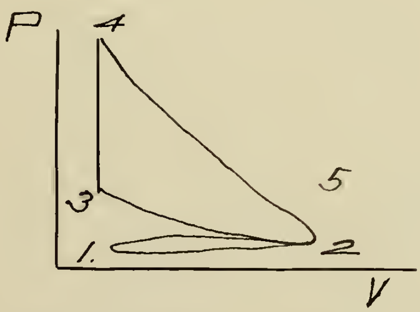
$$= \frac{Jc_v \ (T_b - T_a) - (T_c - T_d)}{Jc_v(T_b - T_a)}$$

$$= 1 - \frac{T_c - T_d}{T_b - T_a}$$

$$= 1 - \frac{T_d}{T_a}$$

The cycle shown above is the ideal case of the Otto cycle, the actual cycle approaches this cycle as shown below.





The actual cycle is as follows: Air and gas is drawn into the cylinder from (1 - 2). It is compressed from (2-3) at 3 the mixture is ignited and the pressure and temperature rises along (3-4). From (4-5) the charge expands adiabatically, at

(5) the exhaust opens and burnt gases are exhausted into the atmosphere.

As shown above the efficiency is:

$$= 1 - \frac{T_d}{T_a}$$

which is equal to,

$$= 1 - \left(\frac{P_d}{P_a}\right)^{\frac{K-1}{K}}$$

DESCRIPTION OF ENGINE AND APPARATUS.

The object of these tests is to determine, the gasoline consumption per Brake Horse Power, the efficiency and the heat Balance.

In all the tests the brake load was kept constant during the test.

TEST OF ENGINE NO. 1. The first engine tested was the regular four horse power engine as made by ~~the~~ Root, Van Devort and Co. of Moline Ill. It is of the ordinary horizontal single cylinder type having a 8 inch stroke and a 6 in. cylinder diameter. The average speed was 338 revolutions per minute. The governing is done by cutting off a portion of the incoming charge by a small butterfly valve, accuated by the ordinary two ball governor. The exhaust valve was mechanically operated but the intake valve was opened by the incoming charge.

The regular pump fitted to the engine did not give good satisfaction, so it was removed and the gasoline was feed direct to the mixing valve.

This engine was in very poor condition and had only a small compression, which was due to a bad cut on the inside of the cylinder, caused by the wrist pin.

All the tests were made with the exhaust direct into the air, no muffler being used.

GASOLINE: The amount of gasoline was found by weighing. In preparing for the test, a tank was made of 3 inch gas pipe and a gauge glass placed on one side of it. The height of the

gasoline was read at the beginning of the test and at the end. Then by weighing the gasoline in supply can and filling up tank and reweighing, the amount used was found.

JACKET WATER: The cooling water was taken direct from the city water mains passed through the jacket and caught and weighed in a large tank as it came out. The temperature of the water was measured by thermometers placed in the water before it reached the jacket and at the exit from the jacket.

SPEED: The revolutions per minute were taken every five minutes by a speed indicator. An average of these readings was taken in finding the brake horse power.

BRAKE HORSE POWER: A prony brake as shown in Sketch No. 1 was used in finding the delivered horse power. The determination of the horse power from scale reading of a prony brake is given below.

Where,

l = length of brake arm in feet.

w = load as read from scale.

n = revolutions per minute.

Then, $2\pi l$ = the circumference of a circle about which the end of the brake arm would act, were it free. A force of w pounds acts at the end of the brake arm and the work done is the same as if w pounds passed around the circumference of a circle with l as a radius.

Then, $2\pi lw$ = the foot pounds of work for each revolution of the engine. The engine makes n revolutions per minute.

Then, $2\pi lwn$ = the work per minute.

One Horse Power = 33000 foot pounds per minute.

$$\text{Then, Horse Power} = \frac{2\pi l\ w\ n}{33000}$$

DESCRIPTION OF ENGINE NO. 2.

The second engine tested wasthe regular 2 Horse Power engine as made by Root, Van Devort and Co., of Moline, Illinois. It is of the ordinary vertical single cylinder type having a 4 3/4 in. bore and a stroke of 5 1/2 inches. The average speed was 457 revolutions per minute. The governing was done by holding the exhaust valve open and shutting off the spark, when the exhaust valve was open, a new charge was not drawn in.

The exhaust valve was mechanically operated but intake valve was opened by the incoming charge.

The pump fitted to the engine was not arranged so that the amount of gasoline could be recorded so it was removed and a Kingstone Carburator was fitted to the engine.

The engine was tested without a muffler connected to it and exhausted direct into the air.

READINGS: All readings of gasoline, water, brake horse power and speed were taken in a similar manner as in Engine No. 1.

DESCRIPTION OF ENGINE NO. 3.

The third engine tested was the regular 10 horse power engine as made by The Otto Gas Engine Co. of Philadelphia. It is of the ordinary single cylinder type having a 5 3/4 inch cylinder and a 12 1/2 inch stroke. The average speed was 310

revolutions per minute. The governing was effected by means of the ordinary "hit and miss" method.

A muffler was used on this engine. The reading of gasoline, brake horse power, revolutions and jacket water were taken in this test similar to those in the other tests.

READINGS: The readings which are necessary in calculating results, are as follows:

Length of Test.

Revolutions per Minute.

Length of Brake Arm.

Force on scales.

Amount of gasoline used.

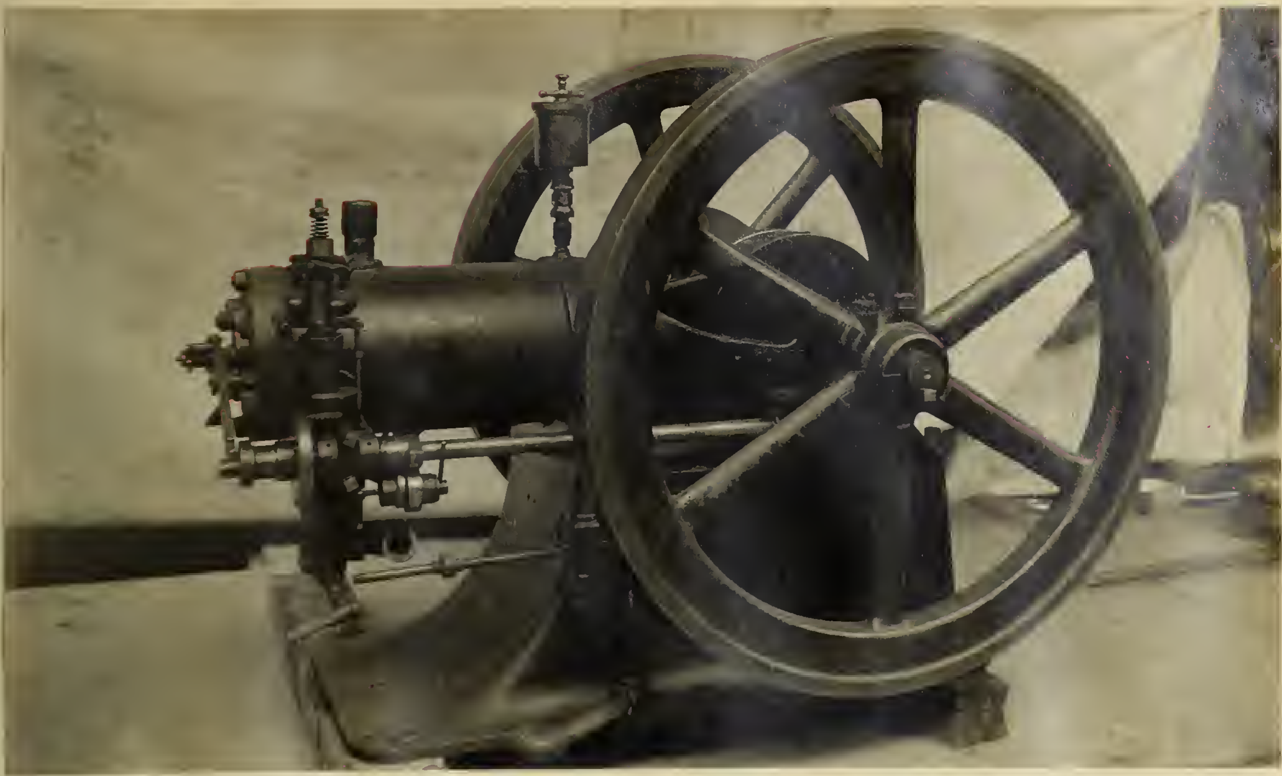
Amount of water used.

Rise in temperature of jacket water.

B.T.U. in Gasoline.

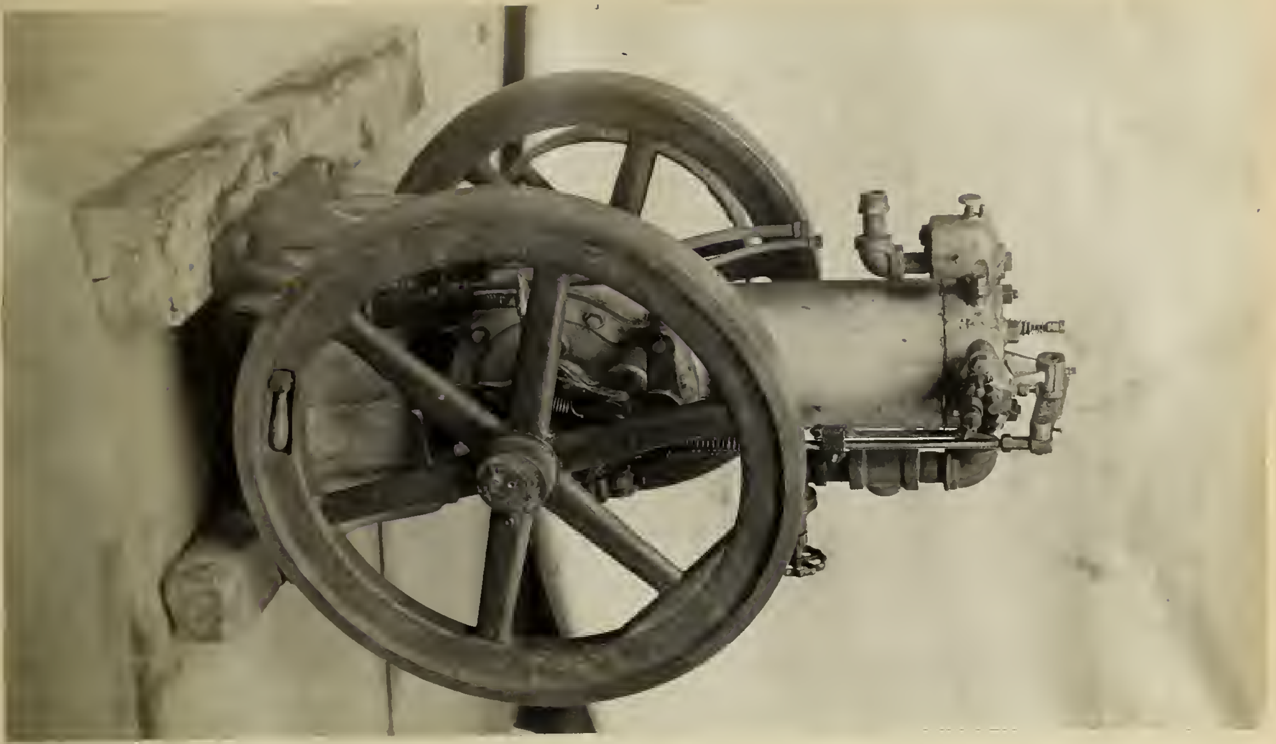
The B.T.U. in a pound of gasoline was determined by the Department of Chemistry and found to be 1~~8~~7000 B.T.U.

4 H.P. Root and Van. Devort Engine.

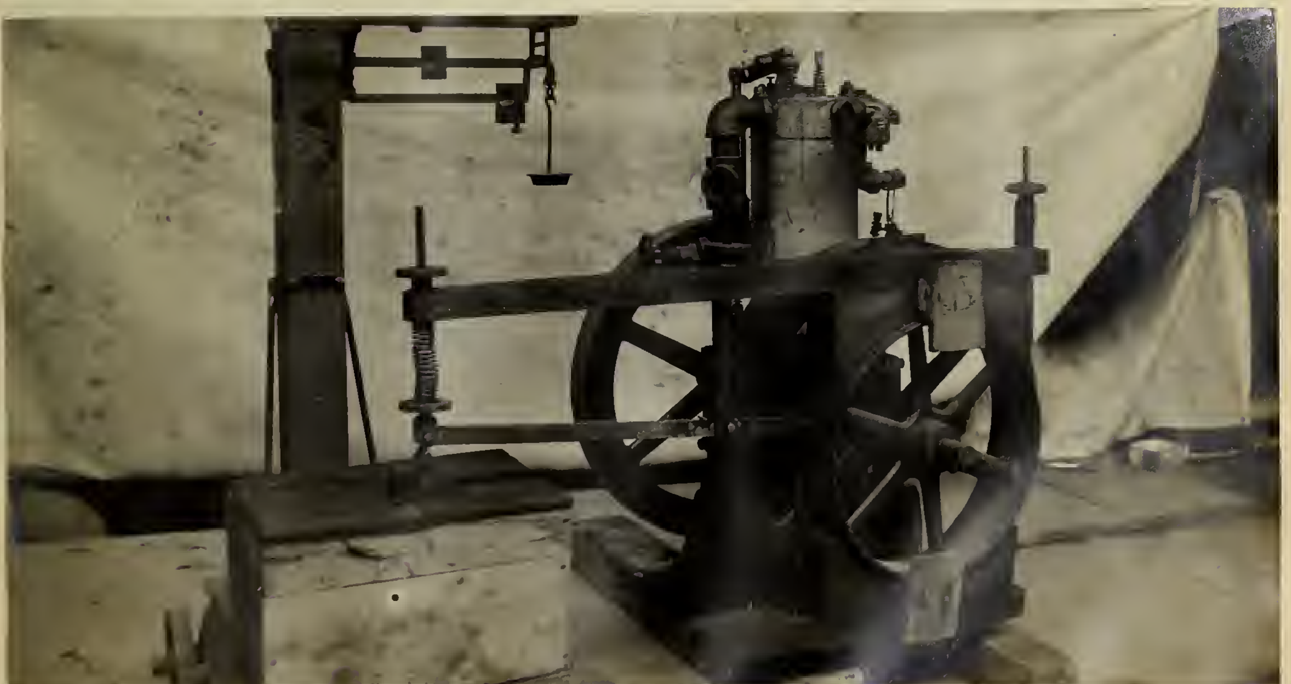


4 H.P. Root and Van. Devort Engine.

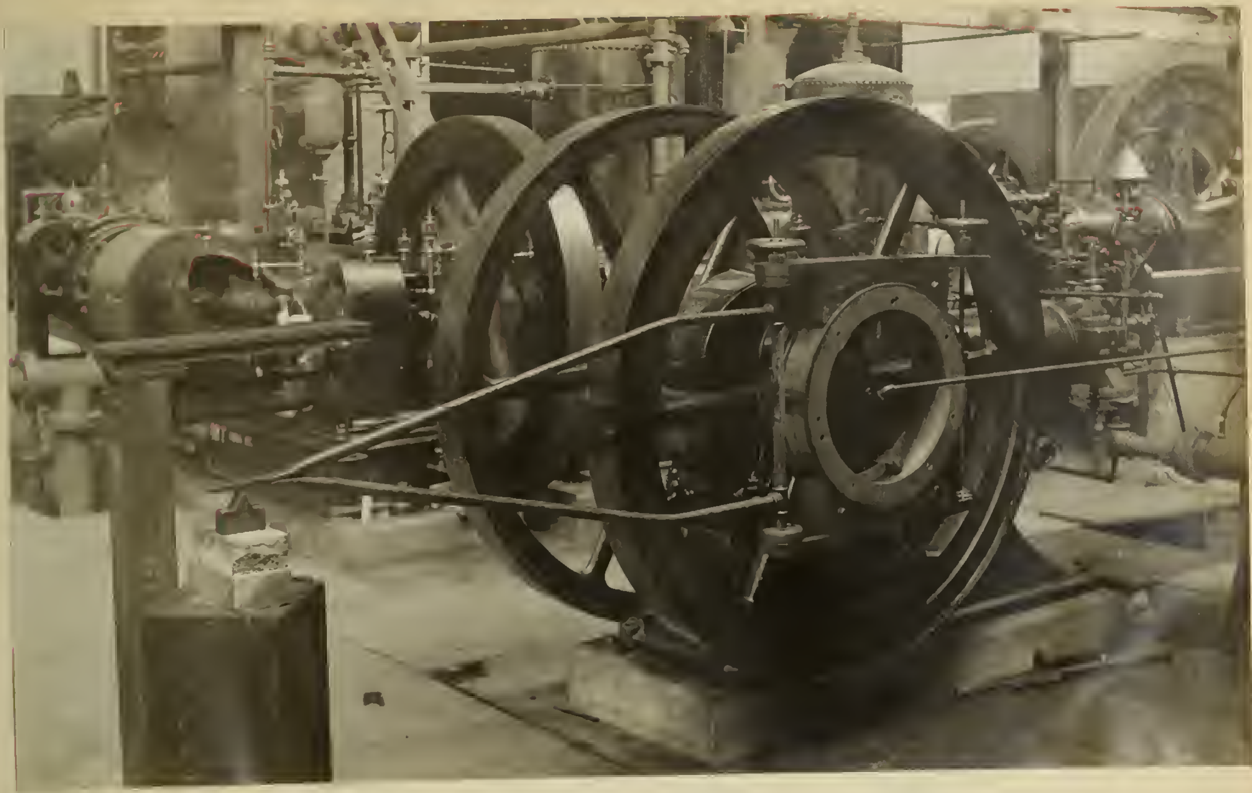
2 H.P. Root and Van. Devort Engine.



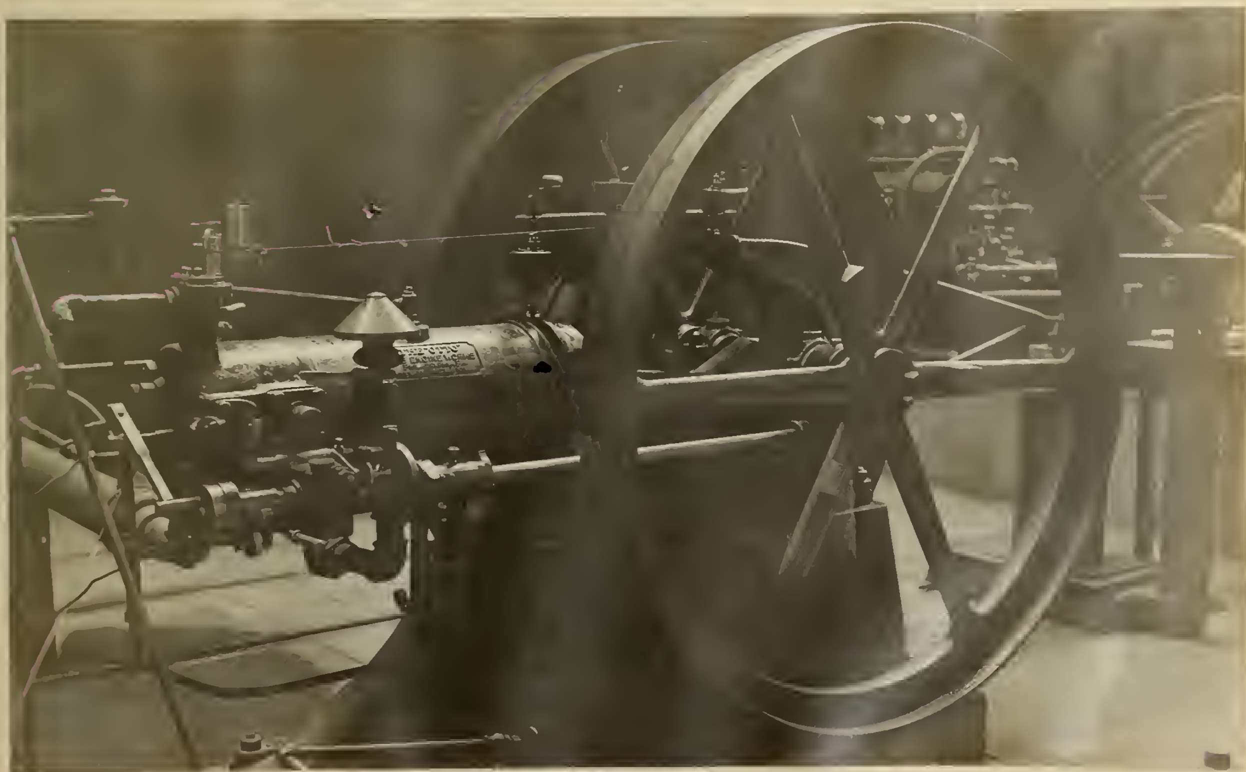
2 H.P. Root and Van. Devort Engine.



IO H.P. Otto Engine.



IO H.P. Otto Engine.



Test of
4 H.P. Root and Van Devort Gasoline Engine

Feb. 24, '06.

Load during test. I5 lb. Gasoline used 3 lb. 5 oz.

Water passing through jacket. 253.5 lbs.

Time.	$T_{I.}$ #	T_2.	R.P.M.
I0:00	68	I22	335
I0:05	69	I24	338
I0:I0	70	I26	338
I0:I5	72	I32	340
I0:20	74	I38	342
I0:25	75	I38	338
I0:30	75	I40	342
I0:35	76	I50	34I
I0:40	76	I52	342
I0:45	76	I50	34I
I0:50	77	I5I	339
I0:55	77	I55	390
II:00	77	I54	342
Ave.	74	I40.9	339.76

#TI Temp. of incoming water. T_2 Temp. of water leaving.

This notation is used in all tables following.

Test of

Root and Van. Devort Gasoline Engine.
Feb. I7, '06.

Load during test. IO lbs.   Gasoline used. 4 lbs. 2 oz.

Water passing through jacket. 342 lbs.

Time	T_I	T_2	R.P.M.
IO:40	68	I20	337
IO:45	68	I26	352
IO:50	76	I34	356
IO:55	80	I42	348
II:00	78	I42	346
II:05	80	I66	346
II:IO	86	I62	343
II:I5	88	I88	346
II:20	86	I60	342
II:25	8I	IIO	336
II:30	80	IIO	347
II: 35	'o	II2	348
II:40	79	IIO	346
Ave.	79.23	I27.07I	345.6

Test of

Root and Van. Devort gasoline Engine.

Feb. 23, '06.

Load during test. 25 lbs.   Gasoline used. 4 lbs. I3 oz.

Water passing throagh jacket. 386 lbs.

Time.	T_I.	T2.	R.P.M.
2:30	68	I00	335
2:35	67	I20	333
2:40	68	I30	332
2:45	68	I34	335
2:50	69	I4I	334
2:55	70	I52	335
3:00	80	I48	330
3:05	70	I50	335
3:I0	70	I48	333
3:I5	70	I47	333
3:20	70	I40	330
3:25	70	I46	333
3:30	70	I46	335
Ave.	68.84	I38.6I	333.38

Test of

Root and Van Devort Gasoline Engine.

Feb. I7, '06.

Load during test. 20 lbs. Gasoline used. 3 lbs. 7 oz.

Water passing through jacket. 40I lbs.

Time.	T_1.	T_2.	R.P.M.
I:55	70	II6	340
2:00	72	I08	338
2:05	76	II0	337
2:I0	77	II3	336
2:I5	77	I05	336
2:20	77	I22	333
2:25	77	I28	338
2:30	77	I30	335
2:35	77	I30	337
2:40	77	I3o	334
2:45	77	I26	322
2:50	78	I26	326
2:55	78	I22	322
Ave.	76.I4	I20.46	333.38

Test of

2 H.P. Root and Van Devort Gasolene Engine

March 17, '06.

Load during test. 3.5 lb. Gasoline used. 1 lb. 4 oz.
Water passing through jacket. 105.5 lbs.

Time .	T_1.	T_2.	R.P.M.
2:35	57	90	470
2:40	57	86	474
2:45	55	92	460
2:50	55	92	470
2:55	54	93	465
3:00	54	96	468
3:05	55	100	462
3:10	54	101	464
3:15	54	104	465
3:20	54	111	462
3:25	54	118	460
3:30	54	112	460
3:35	54	116	450
Ave.	54.69	100.846	463.84

Test of

2 H.P. Root and Van Devort Gas Engine.

March 17, '06.

Load during test. 6.5 lbs. Gasoline used. 1 lb. 5 oz.

Water passing through jacket. 63 lbs.

Time.	T_1.	T_2.	R.P.M.
4:00	75	130	460
4:05	77	319	454
4:10	76	140	460
4:15	73	146	450
4:20	70	138	448
4:25	68	120	447
4:30	66	118	454
4:35	66	120	456
4:40	63	120	457
4:45	60	121	462
4:50	60	134	454
4:55	60	126	454
5:00	60	122	454
Ave.	67.23	129.46	454.61

Test of

2 H.P. Root and Van Devort Gas Engine.

March 16, '06.

Load during test. 12 lb. Gasoline used. 2 lb. 6.5 oz.

Water passing through jacket. 106.5 lbs.

Time.	T_1.	T_2.	R.P.M.
4:20	56	126	466
4:25	56	130	464
4:30	56	132	462
4:35	57	136	458
4:40	57	138	450
4:45	57	139	450
4:50	57	143	456
4:55	57	143	452
5:00	57	154	453
4:05	57	154	448
5:10	57	145	450
5:15	57	146	454
5:20	57	136	454
Ave.	56.77	140.15	455.15

Test of

2 H.P. Root and Van Devort Vertical Engine.

Load during test. 15 lb. Gasoline used. 2 lb. 9 oz.

Water passing through jacket. 179 lb.

Time.	T_1.	T_2.	R.P.M.
11:10	53	150	462
11:15	53	162	460
11:20	53	142	464
11:25	54	138	458
11:30	54	144	460
11:35	54	174	456
11:40	54	126	456
11:45	54	120	454
11:50	Missed.		
11:55	54	125	450
12:00	53	120	450
12:05	53	135	445
12:10	53	145	460
Ave.	53.33	140.008	456.25

Test of

10 H.P. Otto Gas Engine.

March 24, '06.

Load during test. 14 lb.   Gasoline used. 4 lb. 1 oz.

Water passing through jacket. 356 lb.

Time.	T_1.	T_2.	R.P.M.
3:40	58	112	310
3:45	58	116	310
3:50	58	118	310
3:55	58	118	312
4:00	58	118	312
4:05	58	120	312
4:10	58	120	311
4:15	58	121	311
4:20	58	120	311
4:25	59	118	312
4:30	59	117	312
4:35	59	124	311
4:40	59	134	312
Ave.	58.15	119.69	311.23

Test of

10 H.P. Otto Gas Engine.

March 23, '06.

Load during test. 27 lb.   Gasoline used. 8 lb. 14 oz.

Water passing through jacket. 407.5 lb.

Time.	T_1.	T_2.	R.P.M.
2:30	65	138	307
2:35	65	170	309
2:40	66	186	310
2:45	67	160	310
2:50	67	152	310
2:55	67	150	310
3:00	67	150	310
3:05	64	150	310
3:10	63	150	310
3:15	63	150	310
3:20	63	150	310
3:25	64	150	310
3:30	64	150	310
Ave.	65.77	152.77	309.69

Test of

Otto Gas Engine.

March 24, '06.

Load during test. 30 lb. Gasoline used. 5.9 lb.

Water passing through jacket. 591 lb.

Time.	T_1.	T_2.	R.P.M.
2:00	64	170	311
2:05	64	175	310
2:10	64	170	308
2:15	64	165	308
2:20	65	165	309
2:25	65	170	309
2:30	65	170	310
2:35	65	180	310
2:40	65	175	309
2:45	64	180	309
2:50	64	165	309
2:55	64	160	310
3:00	64	160	309
Ave.	64	164	309.3

I

1 hour Test of Root and Vandervort Horizontal Engine.

Test was made Feb. 17, '06. 10:40-11:40 A. M.

Average R.P.M. 345.6.

Load on scales 10 lb. Brake arm 2.64 ft.

B.T.U. Absorbed by cooling water = $N(T_2 - T_1)$ =

$$342(127.07 - 79.23) = 16380$$

B.H.P. = $\frac{2 \times 2.66 \times 345.6 \times 10}{33000} = 1.74$

Amount of gasoline used. 4 lb. 2 oz = 4.125 lb.

Total B.T.U. put in = 4.125 x 17200 = 71000

Lbs gasoline used per H.P. hour. = $\frac{4.125}{1.74} = 2.37$ lbs.

B.T.U. used per H.P. hr. = $\frac{71000}{1.74} = 40700$

Useful work $\frac{2544}{40700} = .0625 = 6.25\%$

Jacket water $\frac{16380}{71000} = .2305 = 23.05\%$

Friction in Engine, radiation and exhaust = 70.7%.

II

1 hour test of Root and Vandervort Horizontal Engine.

Test Made Feb. 17, 1906. 1:55-2:55 P.M.

Average R.P.M. 333.38.

Load on scales, 20 lb. Brake arm 2.64 feet.

B.T.U. sbsorbed by cooling water, $N(T_2 - T_1)$ =

a

$$401(120.46 - 76.14) = 17750$$

B.H.P. = $\frac{2 \times 2.64 \times 333.38 \times 20}{33000} = 3.35$

Amount of gasoline used 3 lb. 10 oz. = 3.625 lbs.

B.T.U. put in, 3.625x17200 = 62500

B.T.U. per H.P. hour used. $\frac{62500}{3.35}$ = 18600

Lbs gasoline used per H.P. hour. $\frac{3.625}{3.35}$ = 1.08 lb.

Useful work $\frac{2544.6}{18600}$ = .137 = 13.7%

Jacket water $\frac{17750}{62500}$ = .284 = 28.4%

Friction, radiation, exhaust. = 57.9%.

III

1 Hour Test of Root and Vandervort Horizontal Engine.

Feb 23, '06. 2:30-3:30 P.M.

Average R.P.M. 333.38.

Load on scales, 25 lbs. Brake arm, 2.64 ft.

B.T.U. absorbed by cooling water. $N(T_2 - T_1)$ =

386 (138.61 - 68.84) = 386 (69.77) = 20900

B.E.P., $\frac{2 \quad x333.38x25x2.64}{33000}$ = 4.2

Gasoline used, 4 lb. 13 oz. = 4.813 lb.

B.T.U. put in = 4.813x17200 = 82900

B.T.U. used per H.P. hour. = $\frac{82900}{4.2}$ = 20700

Lbs. Gasoline per H.P. hr. = $\frac{4.813}{4.2}$ = 1.15 lb.

Use ful work = $\frac{2544.6}{20700}$ = 1.23 = 12.3%

Jacket water = $\frac{26900}{82900}$ = .325 = 32.5%

Radiation, friction and exhaust = 55.2%

IV

1 hour Test of Root and Vandervort Horizontal Engine.

Feb. 24, '06. 10:00-11:00

Average R.P.M. 339.76

Load on scales 15 lb. Brake arm 2.64 ft.

B.T.U. absorbed by cooling water, $N(T_2 - T_1) =$

$$253\ (140.92 - 74.) = 253 \times 66.92 = 16900$$

$$\text{B.H.P.} = \frac{2\ \ \times 339.76 \times 15 \times 2.64}{33000} = 2.55$$

Gasoline used, 3 lb. 5 oz. = 3.312 lb.

B.T.U. put in = 3.312 x 17200 = 57000

$$\text{B.T.U. used per H.P. hr.} = \frac{57000}{2.55} = 22300$$

$$\text{Lbs. gasoline per H.P. hr.} = \frac{3.312}{2.55} = 1.3$$

$$\text{Useful work } \frac{2544.6}{22300} = .114 = 11.4\%$$

$$\text{Jacket water} = \frac{16900}{57000} = .297 = 29.7\%$$

Friction, radiation and exhaust = 58.9%

I

1 hour Test of Root and Vandervort Vertical Engine.

March 17, '06. 2:35-3:35.

Average R.P.M. 463,84

Load on scales 3.5 lb. Length of brake arm. 2.64 ft.

B.T.U. absorbed by cooling water $N(T2 - T1) =$

$$105.5(100.84 - 54.69) = 105.5 \times 46.15 = 4650$$

$$\text{B.H.P.} = \frac{2 \times 463.84 \times 3.5 \times 2.64}{33000} = .815$$

Gasoline used, 1 lb. 4 oz. = 1.25 lb.

B.T.U. put in = 1.25x17200 = 21500

B.T.U. used per H.P. hr. $= \frac{21500}{.815} = 26400$

Lbs. gasoline used per H.P. hr. $= \frac{1.25}{.815} = 1.53$ lb.

Useful work, $\frac{2544.6}{26400} = .096 = 9.7\%$

Jacket water $\frac{4650}{21500} = .212 = 21.2\%$

Friction, radiation and exhaust = 100 - 30.9 = 69.1%

II

1 hour Test of Root and Vandervort Vertical Engine.

March 17, '06. 4:00-5:00 P.M.

Average R.P.M. 454.61

Load on scales 6.5 lb. Brake arm 2.64 ft.

B.T.U. absorbed by cooling water $N(T_2 - T_1) =$

$$63(129.46 - 67.23) = 63 \times 62.23 = 3920$$

$$\text{B.H.P.} = \frac{2 \times 454.61 \times 6.5 \times 2.64}{33000} = 1.48$$

Gasoline used 1 lb. 15 oz. = 1.94 lb.

B.T.U. in Gasoline put in. = 1.94 x 17200 = 33 400

B.T.U. used per H.PP hour. $\frac{33400}{1.48}$ = 22500

Lbs. gasoline used per H.P. hour. = $\frac{1.94}{1.48}$ = 1.3

Useful work, $\frac{2544.6}{22500}$ = .113 =11.3%

Jacket water, $\frac{3920}{33400}$ =.117 = 11.7%

Radiation, friction and exhaust = 76%

111

1 hour Test of Rood and Vandervort Vertical Engine.

March, 16, '06. 4:20-5:20.

Average R.P.M. 455.15

Load on scales 12 lb. Brake arm 2.64 ft.

B.T.U. absorbed by cooling water $N(T_2 - T_1)$ =

106.5(140.15 - 56.77) = 106.5 (83.38) =n8850

B.H.P. = $\frac{2 \quad x455.15 \times 12x2.64}{33000}$ = 2.74

Gasoline used 2 lb. 6 1/2 oz. = 2.405 lb.

B.T.U. put in. = 2.405 x 17200) = 41400

B.T.U. used per H.P. hour. $\frac{41400}{2.74}$ = 15100

lbs gasoline used per H.P. hr. = $\frac{2.405}{2.74}$ = .88 lb.

Useful work $\frac{2544.6}{15100}$ = .168 = 16.8%

Jacket water $\frac{8860}{41400}$ = .214 = 21.4%

Radiation, friction, exhaust = 51.8%

IV

1 hr. Test of Root and Vandervort Vertical Engine.

March 24, '06. 11:10-12:10. A.M.

Average R.P.M. 456.25.

Load on scales 15 lb. Brake arm. 2.64 ft.

B.T.U. sbsorbed by colling water $N(T_2 - T_1) =$

$$179\ (140 - 53.3) = 179 \times 867 = 15500$$

$$\text{B.H.P.} = \frac{2 \times 456.25 \times 15 \times 2.64}{33000} = 3.45$$

Gasoline used, 2 lb. 9 oz. = 2.56 lb.

$$\text{B.T.U. used per H.P. hr.} = \frac{44000}{3.45} = 12700$$

$$\text{Lbs. gasoline per H.P. hr.}\ \frac{2.56}{3.45} = .74 \text{ lb.}$$

$$\text{Useful work} = \frac{2544.6}{12700} = .20 = 20\%$$

$$\text{Jacket water}\ \frac{15500}{44000} = 35.2 = 35.2\%$$

Friction, radiation and exhaust = 44.8%

I

1 hour Test of Otto Gas Engine.

Test was made March 23, 1906 2:30-3:30 P.M.

Average R.P.M. 309.7.

Load on Scales 27 lb. Brake arm 5 ft 2 in.

B.T.U. in cooling water = Number of lbs of water times (t -

$(T_2 - T_1)$ where t_2 and T_1 are initial and final temperatures

of water.

Average T_1 equals 65.77 degrees. F.

Average T_2 equals 152.77 degrees F.

Pounds of water used 407.5 = N

B.T.U. in water = 407.5 (152.77 - 65.77) = 35452.5

H.P. = R.P.M. x 2 x length of arm x load divided by 33000.

$$H.P. = \frac{309.7 \times 2 \quad \times 5.166 \times 27}{33000} = 8.23$$

Amount of gasoline used, 8 lb. 14 oz. = 8.876 lb.

B.T.U. put in = 8.875 x 17200 = 152650

$$B.T.U.\ used\ per\ H.P.\ hr. = \frac{152650}{8.23} = 18550$$

$$Lbs.\ gasoline\ per\ H.P.\ hr.\ \frac{8.875}{8.23} = 1.08\ lb.$$

B.T.U. equivalent to H.P. hr. = 2544.6

$$ratio\ of\ \frac{2544.6}{18550} = .1395 = 13.95\%$$

Useful work = 13.95%

$$Jacket\ water = \frac{35452.5}{152650} = .232 = 23.2\%$$

Friction, radiation and exhaust = 52.85%.

II

1 hr. Test of Otto Gas Engine.

Test was made March 24, 1906. 3:40-4:40 P.M.

Load on Scales 14 lbs. Brake arm 5 ft. 2 in.

B.T.U. in cooling water = N(T2 - T1) =

356 (119.69 - 58.15) = 21950

$$\text{B.H.P.} = \frac{2 \times 311.23 \times 5.166 \times 14}{33000} = 4.28$$

R.P.M. = 311.23

Amount of gasoline used = 4 lb. 1oz. = 4.0625 lb.

B.T.U. in gasoline used = 4.0625 x 17200 = 70000

$$\text{B.T.U. used per H.P. hr.} = \frac{70000}{4.28} = 16800$$

$$\text{Lbs. gasoline per H.P. hr.} = \frac{4.0625}{4.28} = .95 \text{ lb.}$$

$$\text{Useful work} = \frac{2544.6}{16300} = .153 = 15.3\ \%$$

$$\text{Jacket water} = \frac{21950}{70000} = .314 = 31.4\%$$

Friction of engine, radiation andexhaust = 53.3 %

III

1 hr. Test of Otto Engine.

Test was made March 24, 1906 2:00-3:00.

Load on scales 30 lb . Brake arm 5 ft. 2 in.

B.T.U. in cooling water $N(T_2 - T_1) =$

591 (164 - 64) = 59100

R.P.M. average 309.3

$$\text{B.H.P.} = \frac{2 \times 309.3 \times 5.166 \times 30}{33000} = 9.1$$

Gasoline used = 5.9 lb.

B.T.U. in gaoline used = 5.9 x 17200 = 108000

B.T.U. per H.P. hr. = $\frac{108000}{9.1}$ = 11200

Lbs gasoline used per H.P. hr. = $\frac{5.9}{9.1}$ = .65

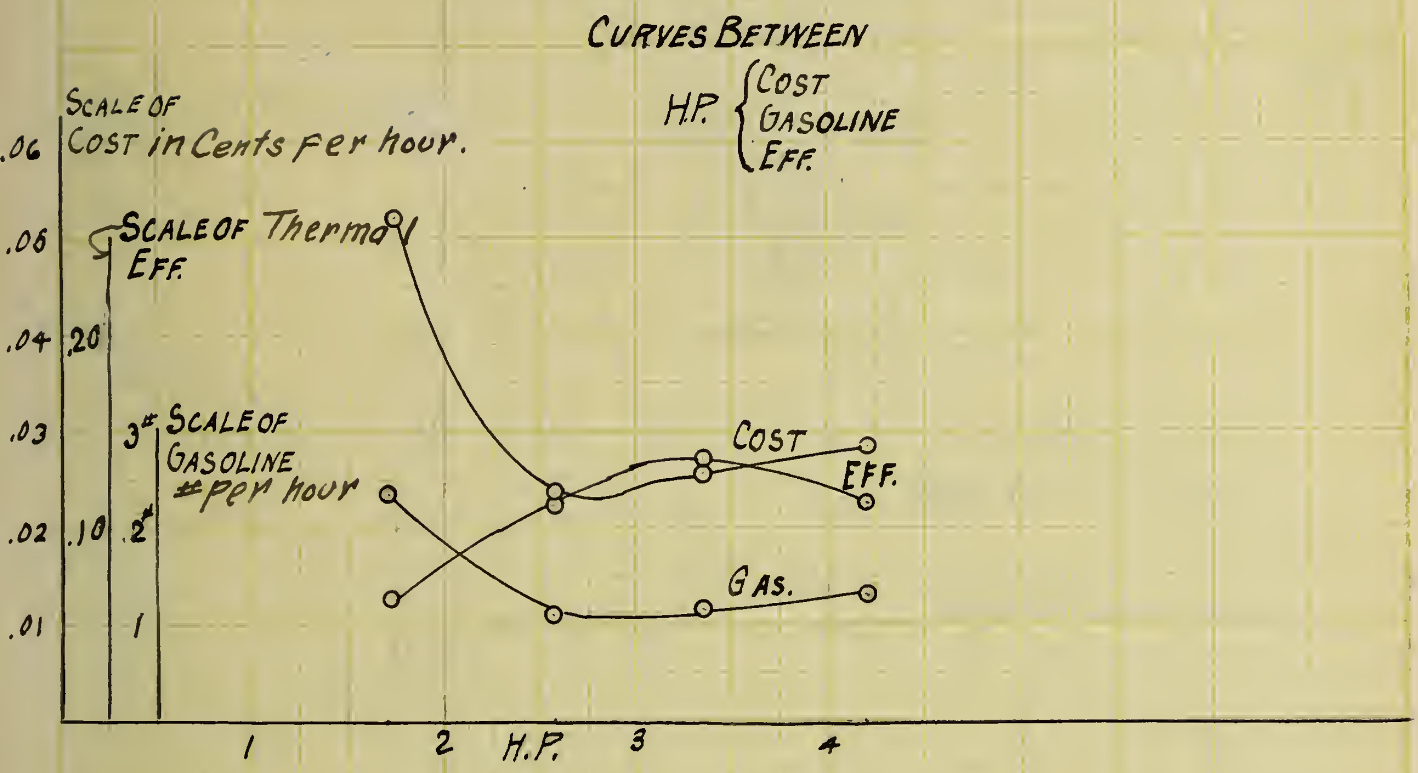
Useful work = $\frac{2545}{11200}$ = .225 = 22.5%

Jacket water = $\frac{59100}{108000}$ = .56 = 56%

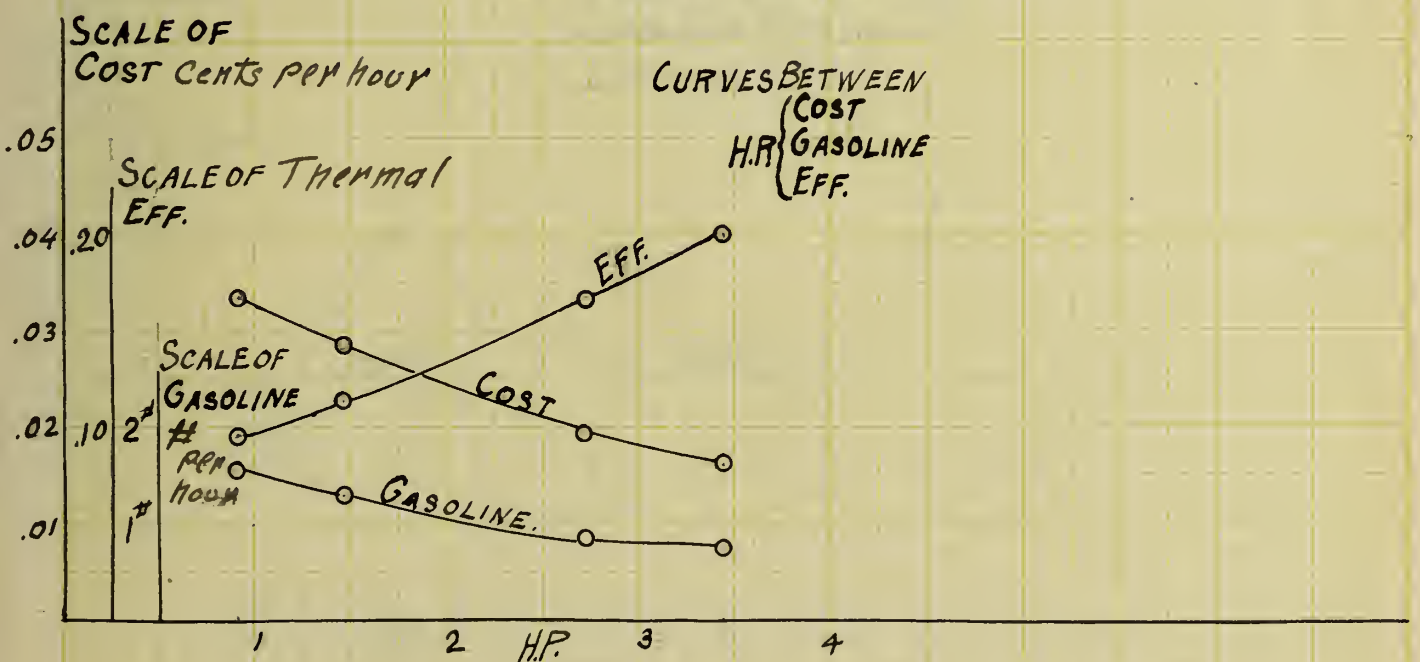
Friction, radiation and exhaust = 21.5%

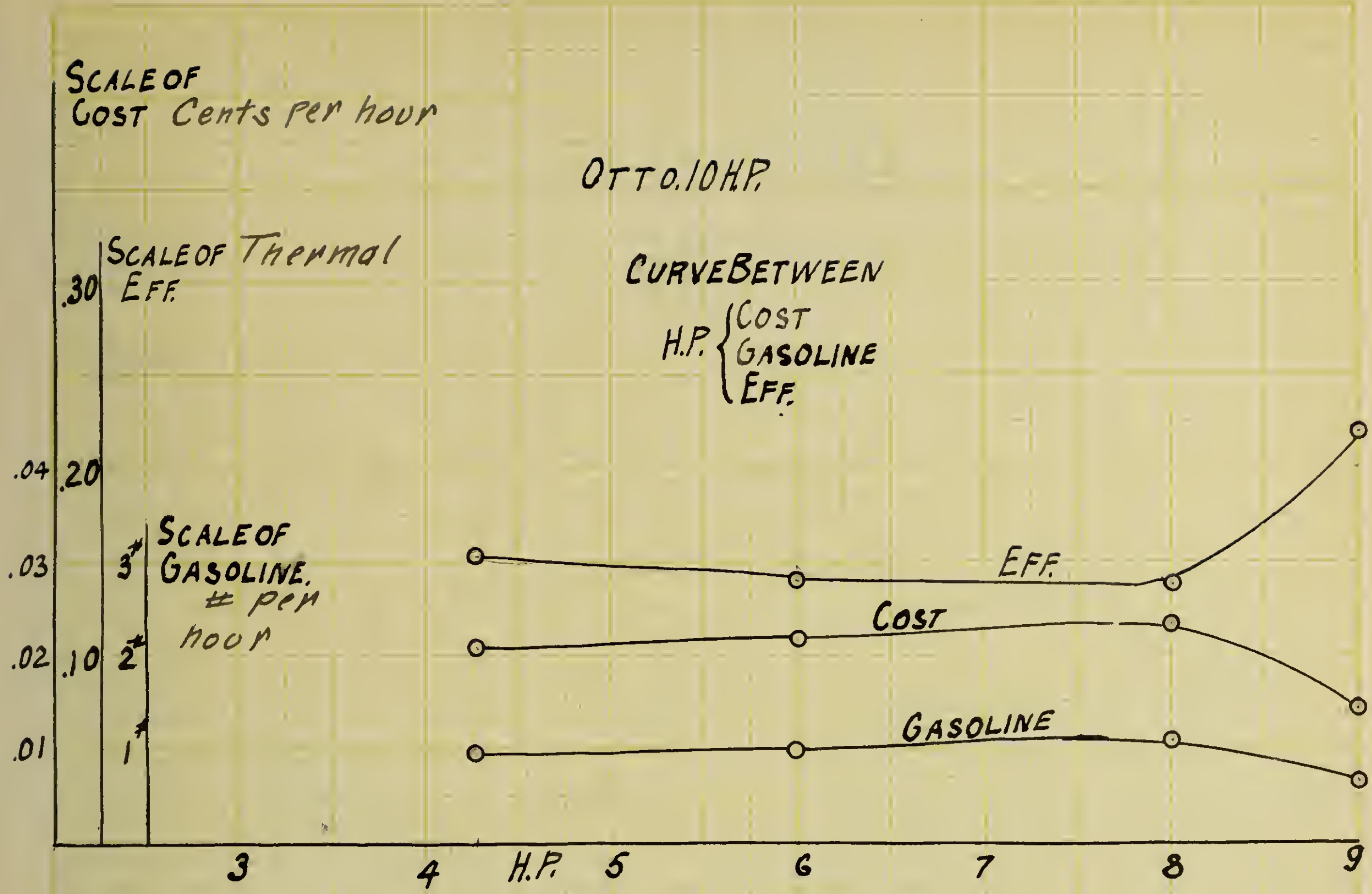
	No of Test	R.P.M.	Brake Load	Length Arm	B.H.P.	Total Gasolene	Gasolene per B.H.P.	Cost of BHP 3000 hrs	BTU per BHP.	% BTU in Work	% BTU in Jacket Water	% BTU in Losses	Thermal Eff
			#	feet		#	#	$					
4 H.P. Root & VanDevort Engine	1	345.6	10	2.64	1.74	4.125	2.37	156.00	40700	6.25	23.05	70.7	6.25
	2.	339.7	15	2.64	2.55	3.312	1.3	71.28	24600	11.4	29.7	58.9	11.4
	3	333.3	20	2.64	3.35	3.625	1.08	75.9	18800	13.7	28.4	57.9	13.7
	4	333.3	25	2.64	4.2	4.81	1.15	85.80	20700	12.3	32.5	55.2	12.3
2 H.P. Root & VanDevort Engine	1	463.8	3.5	2.64	.815	1.25	1.53	100.98	26400	9.7	21.2	69.7	9.7
	2	454.6	6.5	2.64	1.48	1.94	1.3	85.8	22500	11.3	12.7	76	11.3
	3	455.1	12	2.64	2.74	2.405	.88	58.08	15100	16.8	21.4	51.8	16.8
	4	456	15	2.64	3.45	2.56	.74	48.84	12700	20	35.2	44.8	20
10 H.P. Otto Engine	1	311.2	14	4.28	4.06	.95	.95	62.70	16800	15.3	31.4	53.3	15.3
	2	309.7	27	5.16	8.23	8.875	1.08	71.28	25400	13.95	23.2	52.8	13.9
	3	309.3	30	5.16	9.1	5.9	.65	42.9	11200	22.5	56	21.5	22.5

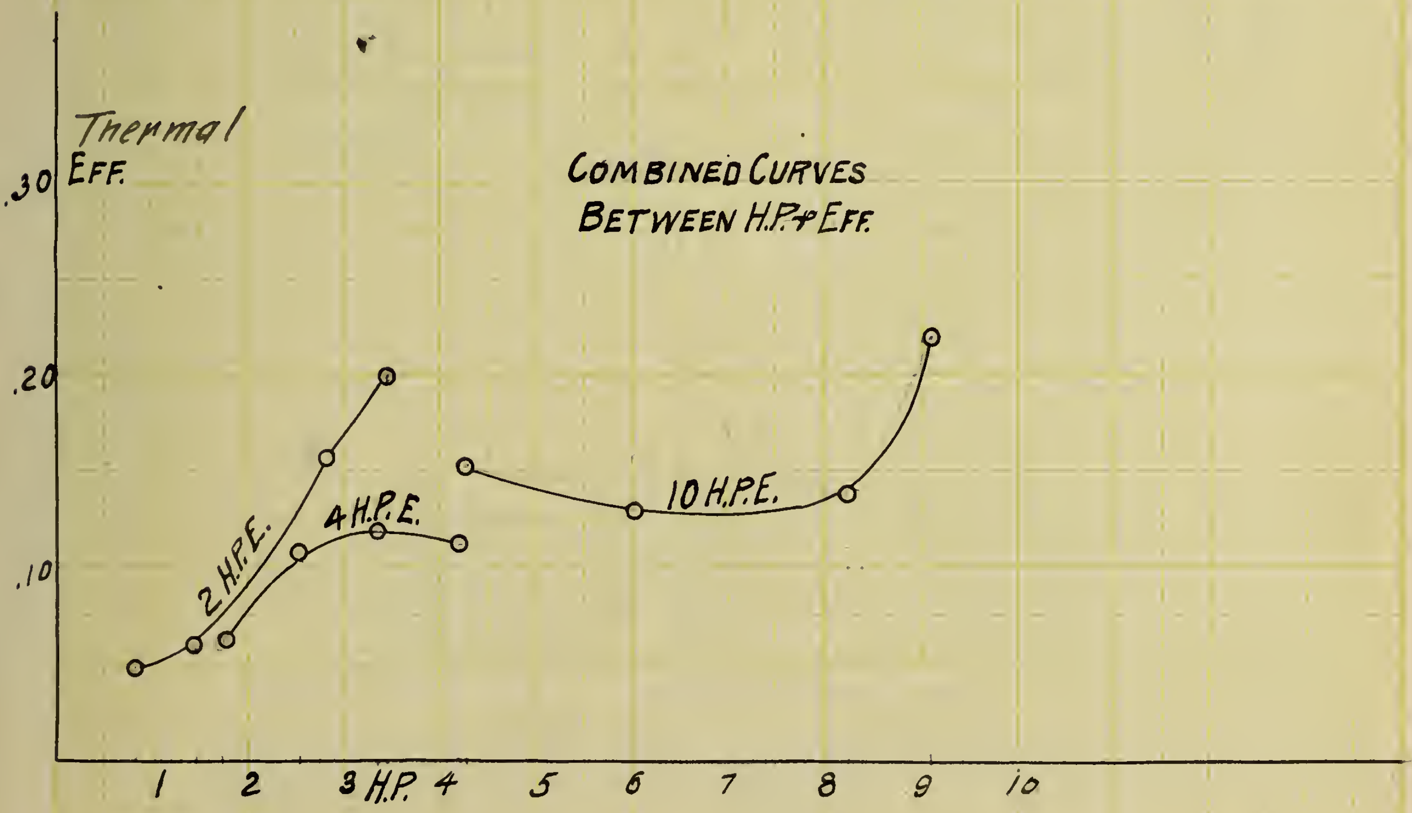
ROOT AND VAN DE VORT 4 H.P.



ROOT AND VAN DE VORT 2 H.P.




Scale of Cost Cents per hour
Otto. 10 H.P.
Scale of Thermal Eff.
Curve Between
H.P. { Cost Gasoline Eff.
Scale of Gasoline. # per hour
.04
.03
.02
.01
.30
.20
.10
3#
2#
1#
Eff.
Cost
Gasoline
3
4
H.P.
5
6
7
8
9


Thermal Eff.
Combined Curves Between H.P. & Eff.
.30
.20
.10
2 H.P.E.
4 H.P.E.
10 H.P.E.
1
2
3 H.P.
4
5
6
7
8
9
10